Modeling Sediment Erosion and Redistribution in Fine-Grained Shelf Environments

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LONG-TERM GOAL

My long-term goal within the EuroSTRATAFORM program is to increase our ability to predict sediment transport in fine-grained regions of the continental shelf. Field work and the development and application of models during STRATAFORM increased our understanding of these processes and improved our ability to predict them. The Adriatic and Gulf of Lions EuroSTRATAFORM sites offer characteristics (forcing, margin configuration) that contrast with the Eel shelf STRATAFORM study area. Testing and extending our conceptual and numerical sediment transport models at these sites is an important goal of the EuroSTRATAFORM shelf process studies.

OBJECTIVES

The objectives of this project are to 1) measure alongshelf, across-shelf and temporal variations in critical shear stress and erosion rates; 2) compare transport rates measured by bottom tripod with values calculated using measured erosion rates; and 3) explore the implications of spatial variations in critical shear stress on patterns of sediment transport and deposition. The objectives during FY03 were to measure erosion rates and critical shear stress along the Apennine coast of the Adriatic during several seasons, to use the results to develop erosion-rate expressions that can be used in models of shelf sediment transport, and to investigate spatial and temporal variations in the measurements.

APPROACH

My approach is to use an erosion chamber that fits onto a core tube to make shipboard measurements of critical shear stress and rates of erosion of freshly collected seabed sediment and to use the results to parameterize erosion rates of fine-grained sediment in sediment transport models.

WORK COMPLETED

1.   Took delivery of and tested the erosion chamber (built by Larry Sanford and Patrick Dickhudt of Horn Point Laboratory, University of Maryland) in November 2002.
2.   Measured erosion rates at 10 sites (at least 2 replicates at each site) along the west coast of the Adriatic during the February 2003 cruise on the Seward Johnson II. Most measurements were made along the 20-m isobath, with a few shallower sites.
3.   Repeated the erosion rate measurements during the June 2003 cruise on the Seward Johnson II.
4.   Processed all erosion test data from the February and June 2003 cruises.

Report Documentation Page

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
30 SEP 2003		**00-00-2003 to 00-00-2003**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Modeling Sediment Erosion and Redistribution in Fine-Grained Shelf Environments	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	8. PERFORMING ORGANIZATION REPORT NUMBER
Department of Environmental Sciences, University of Virginia,,P.O. Box 400123,,Charlottesville,,VA,22904	

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**6**	

5.   Analyzed the erosion test data for seasonal and along-shelf variations in critical shear stress, organic content of eroded sediment, and erosion rates.

RESULTS

Critical shear stress, erosion rates and organic fraction of eroded sediment were measured on core samples collected primarily along the 20-m isobath between the Po River mouth and the Gargano Promontory (Figure 1) during the winter (February) and spring/summer (June) of 2003 to investigate spatial and temporal effects on their values. Measurements were made using a Gust erosion chamber that fit onto the top of 10-cm-diameter core collected using Wheatcroft's hydraulically damped short (~1 m) corer, which minimized disturbance to the bed surface. The erosion chamber applied a range of known stresses (0.01 – 0.4 Pa) to the sediment surface of the core, each of which was maintained for 20-30 min. Water in the chamber was replaced by pumping seawater into the chamber; water leaving the chamber passed through a turbidity sensor that recorded turbidity levels every 0.5s. The water was then collected in bottles, filtered, dried and weighed to obtain the mass of eroded sediment. The results were used to calibrate the turbidity measurements. Filtered material was combusted to obtain organic fraction. Two to four replicates were made at each site.
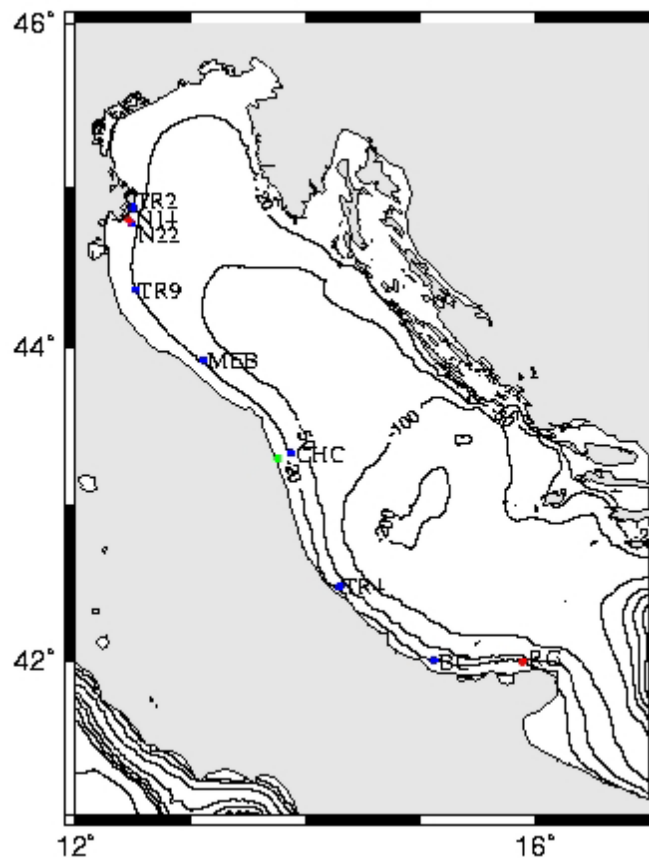

Figure 1. Map of the study area. Locations of the erosion tests are indicated with blue dots for samples collected summer and winter, green dots for winter-only samples and red dots for summer-only samples.

The measurements show a clear seasonal signal with higher erosion rates during winter when organic content was lower (Figure 2). Mean organic fractions of the eroded sediment are relatively high (averages over all February (blue circles) and June (red circles) erosion measurements), especially during the summer measurements (Figure 2a). There is also a general trend of decreasing organic fraction with increasing shear stress. This suggests that the particles intially suspended are disproportionately organic (compared to the bed). The low density or organic particles and the presence of a thin layer of organic-rich particles is present on the bed surface are possible explanations. Time series of concentration of suspended particles in the erosion chamber show no clear critical shear stress in most of the erosion measurements. Mean concentration as a function of shear stress (average of all measurements at each stress) indicates low (essentially background) concentrations at stresses below 0.1 N/m^2. At stresses above 0.1 N/m^2, concentrations increased significantly with shear stress during the winter measurements, but only weakly during the summer measurements. From this it appears that the critical shear stress for significant resuspension during winter was at least 0.1 N/m^2 and could be up to about 0.3 N/m^2 at some locations. During summer, the relatively low concentrations at all stresses suggest that surface erodibility was inhibited, probably by biological coatings (observed in some cores), algal growth and other biological processes, consistent with the higher summer-time organic fractions of resuspended sediment.
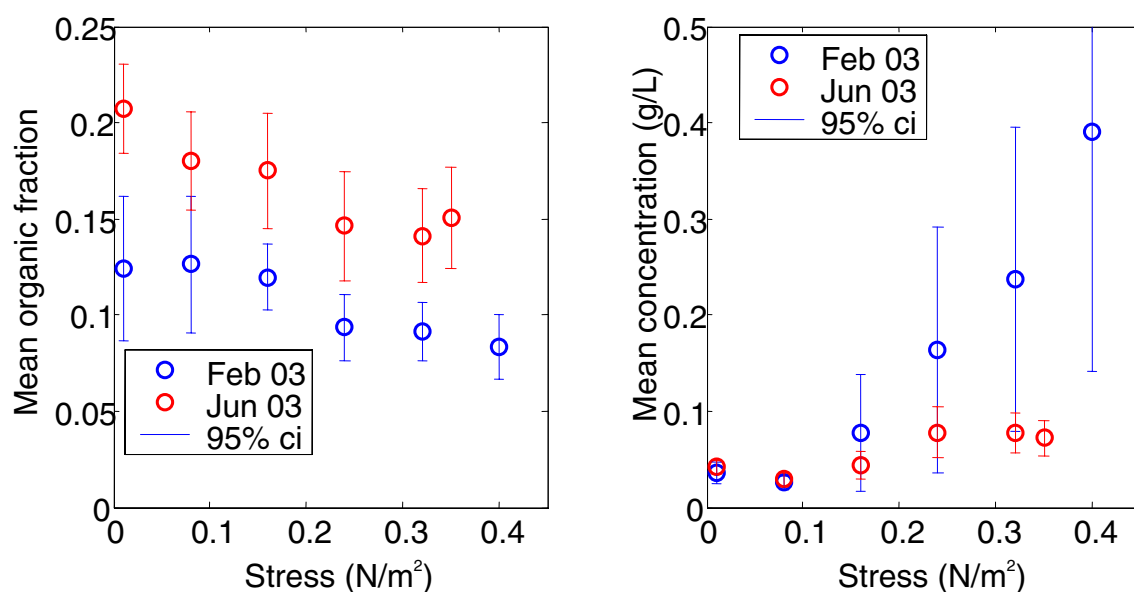

Figure 2. Winter and summer variations in mean organic content and mean concentration as a function of shear stress in erosion tests at the sites indicated in Figure 1. Mean organic fraction decreases with increasing shear stress and is higher overall for the summer measurements. Mean concentration increases significantly at stresses above 0.1 N/m^2 during winter, but only weakly during summer conditions.

Erosion rates vary spatially, but not with any strong alongshelf trend. Generally, winter-time mean concentration, a measure of erosion rate, at a stress of 0.16 N/m^2 (near threshold conditions) is higher

at the northern (near Po River mouth) and southern (near Gargano Promontory) ends of the sampling line than at sites in between, with the highest values as the southern end of the region (Figure 3). At higher stresses (0.32 N/m^2), high concentrations are also measured off the Metauro River. Along-shelf variations in winter organic fraction are similar to the pattern of mean concentration at a stress of 0.16 N/m^2. Some of the variation in concentration among sites may be related to differences in grain size and porosity. Tim Milligan and Rob Wheatcroft will be providing these data.
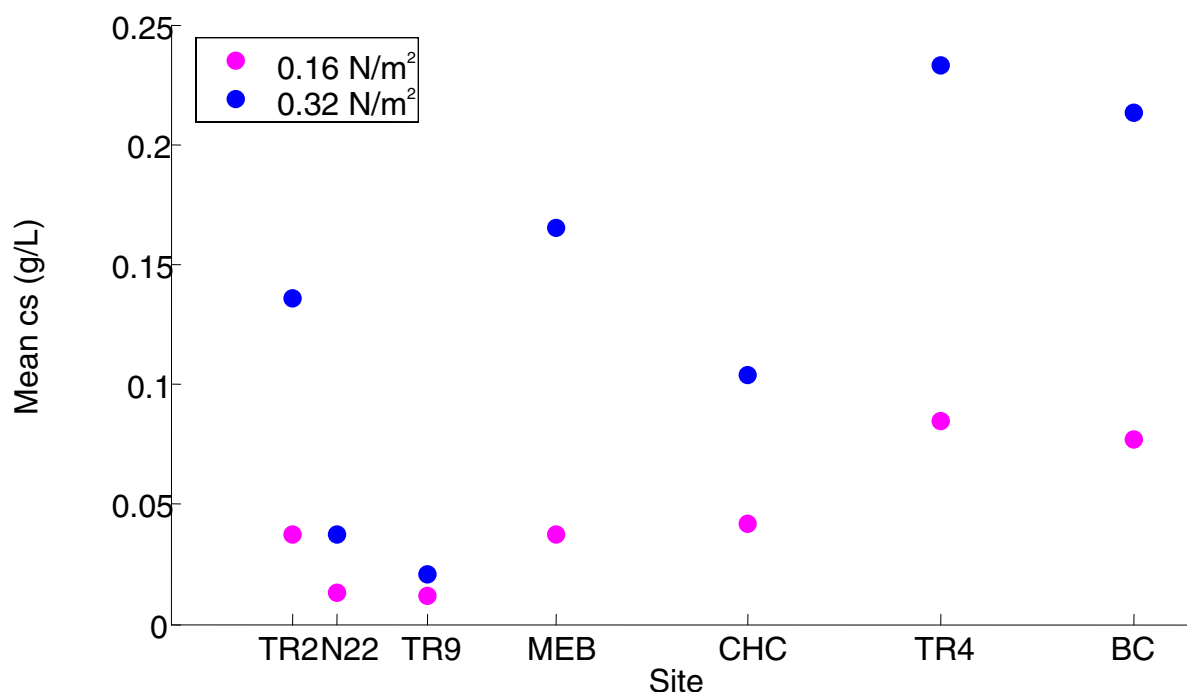

Figure 3. Along-shelf variation in mean concentration in the erosion chamber at stresses of 0.16 N/m^2 (near threshold conditions) and 0.32 N/m^2 at the sampling sites, as identified in Figure 1. Concentrations were generally higher at the northern and southern ends of the sampling region.

Parameterizations of erosion rates based on the measurements are being developed for use in a shelf-sediment transport model and will be compared to near-bed tripod measurements of near-bed suspended-sediment concentration. Relating the mass eroded to the shear stress yields a power-law relationship. Similar results were found by Sanford and Maa (2001) using data from the Sea Carousel, an in-situ flume for measuring critical shear stress and erosion rates. The power-law relationship between eroded mass and shear stress can be transformed into a graph of critical shear stress as a function of depth if the bulk density of the surficial sediment is known and the stress is assumed to be the critical shear stress for the sediment eroded during each shear-stress step. From these, entrainment functions are being formulted that will be used in the sediment transport model. To date, the power-law relationships between shear stress and mass eroded have been developed. In a number of cases, the concentration did not reach background values before the stress was increased, therefore a correction must be applied to related mass eroded vs. shear stress to mass eroded vs. critical shear stress. We are in the process of developing this correction.

IMPACT/APPLICATION

Critical shear stress and erosion rates are among the most poorly constrained parameters in shelf sediment transport calculations. These measurements will improve our ability to specify these important parameters. The field program in the Adriatic provides near-bed sediment transport measurements against which model calculations made using erosion rates determined in this study.

RELATED PROJECTS

The models I am using in this project were developed in the STRATAFORM program.

REFERENCES

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PUBLICATIONS

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